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EVALUATION OF DOMESTIC SLUDGE AS A NUTRITIONAL SOURCE FOR MAIZE (*Zea mays L.*) UNDER KASHMIR TEMPERATE CONDITIONS

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ABSTRACT

Several sewage treatment plants have recently been constructed in Srinagar city (Jammu & Kashmir) around the famous Dal lake but without any proper sewage management consideration. Land-fill as sludge disposal option is not so attractive due to the space limitation in the city. However, recycling sludge for agricultural use may not only serve as an ecofriendly and safe route for sludge disposal but also may improve soil health. Field trials were conducted at Agricultural Research Farm, Krishi Vigyan Kendra, SKUAST-K, Shuhama, Srinagar during *kharif* seasons of 2008-09 and 2009-10 to evaluate the effect of integrated use of locally generated sludge and chemical fertilizers on maize productivity and soil fertility. Highest maize grain yield (4630 kg ha^{-1}), stover yield (7270 kg ha^{-1}) and nutrient contents in grain (15.5 g N, 4.3 g P, 4.8 g K, 32.1 mg Zn, 2.5 mg Cu, 8.5 mg Mn and 26.1 mg Fe kg^{-1}) and stover (6.2 g N, 1.4 g P, 17.2 g K, 39.3 mg Zn, 5.2 mg Cu, 44.8 mg Mn and 242.7 mg Fe kg^{-1}) were found in treatment 75% of recommended NPK + 30 t sludge ha^{-1}. This was followed by statistically at par treatments of 100% recommended NPK + 15 t sludge ha^{-1}, 75% recommended NPK + 15 t sludge ha^{-1} and 50% recommended NPK + 30 t sludge ha^{-1}. Significantly high N, P, K, Zn and Fe uptake by the crop was observed in 75% recommended NPK + 30 t sludge ha^{-1} treatment in comparison to other treatments. The treatments receiving sludge significantly improved organic carbon, available macro-nutrients and DTPA-extractable micro-nutrients in soil over 100% NPK. The study revealed that the integrated use of sludge @ 15 t ha^{-1} + 75-100% recommended NPK or sludge @ 30 t ha^{-1} + 50-75% recommended NPK may help in sustaining maize yield and improving soil health under climatic conditions of Lesser Himalayas.

Key words: Chemical fertilizers, domestic sludge, integrated nutrient use, soil health, yield

INTRODUCTION

With the rapid urbanization and increase in human population, the municipal waste generation has increased tremendously with each passing day. Most of these wastes are disposed off in land-fills or dumped in towns and cities which, in turn, cause serious environmental consequences in the form of global warming through emission of green-house gases (Mantis *et al.*, 2005; Paramasivam *et al.*, 2008). Recently Jammu & Kashmir government constructed several sewage treatment plants in Srinagar city around the famous Dal lake. These plants continuously treat the sewage received from domestic establishments and discharge sewage water into fresh water reservoirs, whereas the sludge is disposed off via open dumps on the outskirts of city. Since sewage sludge contains a substantial load of pathogenic bacteria and viruses, and also emits foul smell, this improper disposal method is considered as one of the major causes of environmental pollution and public health risk.

The use of chemical, physical and biological properties of soil as a living filter appears a solution to mitigate soil and water pollution arising from the current waste disposal processes. Agricultural lands are excellent sites for utilizing sewage sludge as a conditioner or fertilizer containing organic matter and plant nutrients (Aggelides and Londra, 2000; Rowell *et al.*, 2001). The use of sludge in agricultural land may prove an excellent substitute for costly fertilizer inputs and can be cost-effective not only for the municipalities generating this by-product but also to the farmers who accept it. Integrated plant nutrient supply (INPS) is a concept that aims at to manage and supply the nutrients to plants through chemical fertilizers and exploit all the possible organic sources to optimum level for sustaining the desired crop productivity with simultaneous conservation of natural resources and maintenance of environmental quality (Parr *et al.*, 1989; Milkha, 2010). Therefore, it is more rational to use a management system that incorporates sludge and chemical fertilizers in suitable proportion in a specific crop improvement programme. In view of above, field experiments were conducted to assess the impact of integrated use of domestic sludge and chemical fertilizers on the productivity of maize which is one of the dominant crops cultivated by farmers in Lesser Himalayan belts.

MATERIALS AND METHODS

The present study was undertaken during *kharif* seasons (summer) of 2008-09 and 2009-10 in Lesser Himalayan zone at Agricultural Research Farm, Krishi Vigyan Kendra, SKUAST-Kahmir, Shuhama, Srinagar (34°11′N, 74°49′E, 1639 m amsl). The soil of experimental site was silty clay-loam in texture and nearly neutral in reaction. The experiment comprized of nine treatments; each replicated thrice in a completely randomized block design. Maize (*Zea mays* L.) cv. 'Super Maize' composite was sown in plots of 5 m x 3 m size as a test crop. The treatments were control (no NPK or sewage sludge application); 100% recommended NPK; 100% recommended NPK + 15 t sludge ha^{-1}; 50% recommended NPK + 15 t sludge ha^{-1}; 50% recommended NPK + 30 t sludge ha^{-1}; 75% recommended NPK + 15 t sludge ha^{-1}; 75% recommended NPK + 30 t sludge ha^{-1}; 15 t sludge ha^{-1} and 30 t sludge ha^{-1}. The 100% recommended NPK for maize, based on soil test, was 120 kg N, 26 kg P and 33 kg K ha^{-1}. The sludge was collected in bulk from the Waste Water Treatment Plant, Hazratbal, Srinagar (J&K). The plant treats only domestic sewage of the area. For treatments, well decomposed and air-dried sludge was incorporated into the plots just 15 days before crop sowing. The fertilizers, as per treatments, were applied in the form of urea, diammonium phosphate and muriate of potash at sowing time. The quantity of nitrogen added via diammonium phosphate was adjusted in urea. The crop was harvested at maturity and grain and stover yields recorded. The harvest index was calculated as the ratio of grain to grain plus stover yield and multiplied by 100.

The surface soil samples, collected from the experimental field before sowing and after crop harvest, were air-dried, ground, passed through a 2 mm sieve and analyzed for pH, electrical conductivity, organic carbon and available N, P and K using standard procedures (Tandon, 1993). Soil samples were extracted with DTPA (Lindsay and Norvell, 1978) and the levels of extractable Zn, Cu, Mn and Fe in filtrates determined by atomic absorption spectrophotometer. The nitrogen content in processed sludge, grain and stover samples was determined by Kjeldahl method (Jackson, 1973). The nitrogen content in grain was multiplied by a factor of 6.25 to obtain crude protein (Nicholas and Nason, 1957). Sludge and plant samples were digested in 2:1 HNO_3-$HClO_4$ mixture and phosphorus content in the extracts determined by colorimetric method, potassium by flame photometric method and zinc, copper, manganese and iron by atomic absorption spectrophotometric method (Jackson, 1973). The data was statistically judged by the critical difference test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The physico-chemical characteristics of domestic sludge and soil are given in Table 1. The levels of toxic metals such as cadmium and lead in sludge were below the permissible limits for application to agricultural land (Witter, 1996).

Yield and harvest index

All the treatments significantly influenced the yield of maize in comparison to control (Table 2). The application of 75% recommended NPK + 30 t sludge ha^{-1} gave highest yields of grain (4630 kg ha^{-1}), stover (7270 kg ha^{-1}) and protein (97 g kg^{-1} grain) followed by 100% recommended NPK + 15 t sludge ha^{-1}, 75% recommended NPK + 15 t sludge ha^{-1} and 50% recommended NPK + 30 t sludge ha^{-1}. These treatments were at par for all the above parameters, except that 75% recommended NPK + 30 t sludge ha^{-1} was significantly superior in grain yield over 50% recommended NPK + 30 t sludge ha^{-1}. Treatments, 75% recommended NPK +30 t sludge ha^{-1} and 100% recommended NPK + 15 t sludge ha^{-1} were significantly superior over 100% recommended NPK for grain yield. Treatments, 50% recommended NPK + 30 t sludge ha^{-1} and 50% recommended NPK + 15 t sludge ha^{-1} were at par with 100% recommended NPK for grain, stover and protein yields. The results indicate that to achieve higher and statistically equivalent maize yields, either 75-100% recommended NPK must be applied with 15 t sludge ha^{-1} or 50-75% recommended NPK with 30 t sludge ha^{-1} must be applied to the field. Higher yields due to the integrated use of sludge with chemical fertilizers could be explained on the basis of improvement in physical and nutritional environment of soil and increased nutrient availability and uptake by the crop. Al Zoubi *et al.* (2008) related higher productivity of maize to better physical and nutritional properties of soil caused by the sludge application. Tamrabet *et al.* (2009) found that 30 t sewage sludge ha^{-1} was as efficient as 66 kg mineral nitrogen ha^{-1} in enhancing grain and straw yields of wheat. Bhat *et al.* (2011a,b) observed increase in dry matter accumulation and reduction in the toxic heavy metals in maize and radish with higher digested sludge levels applied to Gangetic alluvial soils of India. The performance of various treatments on the basis of harvest index values (Table 2) could be placed in the order, control <15 t sludge ha^{-1} <30 t sludge ha^{-1} <50% recommended NPK + 15 t sludge ha^{-1} <100% recommended NPK <50% recommended NPK + 30 t sludge ha^{-1} <75% recommended NPK + 15 t sludge ha^{-1} <100% recommended NPK + 15 t sludge ha^{-1} <75% recommended NPK + 30 t sludge ha^{-1}.

Table 1: Physico-chemical characteristics of soil and domestic sludge

Characteristics	Soil	Domestic sludge
Moisture content (%)	-	31.5±1.5
Particle size (mm)	-	≤2.5
pH (1:2.5)	7.20	6.6±0.1
EC (dS m^{-1})	0.12	4.9±0.2
Organic carbon (g kg^{-1})	5.40	116.5±8.5
*Nitrogen (g kg^{-1})	95.50	17.5±0.5
*Phosphorus (g kg^{-1})	7.50	1.0±0.2
*Potassium (g kg^{-1})	141.40	12.0±1.0
*Zinc (mg kg^{-1})	0.50	564.0±27
*Copper (mg kg^{-1})	0.90	527.0±24
*Manganese (mg kg^{-1})	5.80	592.0±19
*Iron (mg kg^{-1})	6.50	11470±1940

*Available contents in soil and total contents in sludge

Table 2: Effect of integrated use of domestic sludge and fertilizers on yield and harvest index of maize

Treatments	Mean yield* (kg ha^{-1}) Grain	Mean yield* (kg ha^{-1}) Stover	Protein (g kg^{-1}grain)	Harvest index (%)
Control	730^{d}	2680^{c}	59	21.4
100% recommended NPK	3570^{b}	6430^{a}	88^{a,b}	35.7
100% recommended NPK + 15 t sludge ha^{-1}	4360^{a}	7140^{a}	96^{a}	37.9
50% recommended NPK + 15 t sludge ha^{-1}	3380^{b}	6220^{a}	86^{b,c}	35.2
50% recommended NPK + 30 t sludge ha^{-1}	3820^{b}	6540^{a}	91^{a}	36.9
75% recommended NPK + 15 t sludge ha^{-1}	4000^{a,b}	6720^{a}	93^{a}	37.3
75% recommended NPK + 30 t sludge ha^{-1}	4630^{a}	7270^{a}	97^{a}	38.9
15 t sludge ha^{-1}	1360^{c,d}	3740^{b,c}	69^{d}	26.7
30 t sludge ha^{-1}	1940^{c}	4460^{b}	78^{c,d}	30.3
$CD_{0.05}$	630	1580	9.4	-

Data followed by the same superscripted letter are statistically similar at $P_{0.05}$

*The values given are the mean of two years data (2008-2009 and 2009-2010)

Chemical composition and nutrient uptake

The concentrations of nutrients reached to a maximum of 15.5 g nitrogen, 4.3 g phosphorus, 4.8 g potassium, 32.1 mg zinc, 2.5 mg copper, 8.5 mg manganese and 26.1 mg iron kg^{-1} in grain and 6.2 g nitrogen, 1.4 g phosphorus, 17.2 g potassium, 39.3 mg zinc, 5.2 mg copper, 44.8 mg manganese and 242.7 mg iron kg^{-1} in stover with the application of 75% recommended NPK + 30 t sludge ha^{-1} (Table 3). These values were within the reference sources of critical values (10-25 g N, 2-6 g P, 2-4 g K and 1-5 mg Cu kg^{-1} in grain) quoted by Urricariet *et al.* (2004). Treatments, 100% recommended NPK + 15 t sludge ha^{-1}, 75% recommended NPK + 15 t sludge ha^{-1} and 50% recommended NPK + 30 t sludge ha^{-1} were statistically similar to the treatment 75% recommended NPK + 30 t sludge ha^{-1} for all the nutrient contents in case of both grain and stover of maize. The maximum nutrient uptake by the crop (116.9 kg N, 30.1 kg P, 147.2 kg K, 434.2 g Zn, 49.8 g Cu, 364.8 g Mn and 1884.0 g Fe ha^{-1}) was achieved in 75% recommended NPK + 30 t sludge ha^{-1} followed by 100% recommended NPK + 15 t sludge ha^{-1}, 75% recommended NPK + 15 t sludge ha^{-1} and 50% recommended NPK + 30 t sludge ha^{-1} (Table 4). Treatment, 75% recommended NPK + 30 t sludge ha^{-1} proved significantly superior over all other treatments with respect to the uptake of nitrogen, phosphorus, potassium, zinc and iron; however it was at par with the 100% recommended NPK + 15 t sludge ha^{-1} treatment for the uptake of copper and manganese. Treatment, 100% recommended NPK + 15 t sludge ha^{-1} was significantly superior over 75% recommended NPK + 15 t sludge ha^{-1} and 50% recommended NPK + 30 t sludge ha^{-1} treatments for the uptake of all the nutrients. Increased nutrient uptake observed in the present study could be assigned to improvement in nutrient-use efficiency on account of integrated use of domestic sludge and chemical fertilizers. Our results are in agreement with Christodoulakis and Margaris (1996) and Zhao *et al.* (2012).

Soil health

Significant decrease in pH and increase in organic carbon, available macro-nutrient (N, P & K) and DTPA-extractable micro-nutrient (Zn, Cu, Fe & Mn) contents was observed in soils receiving domestic sludge as compared to 100% recommended NPK. An increase in electrical conductivity was observed in

Table 3: Effect of integrated use of domestic sludge and fertilizers on the nutrient contents in maize (pooled 2008-09 and 2009-10)

Treatments	Chemical composition													
	Grain							Stover						
	N	P	K	Zn	Cu	Mn	Fe	N	P	K	Zn	Cu	Mn	Fe
	(g kg^{-1})			(mg kg^{-1})				(g kg^{-1})			(mg kg^{-1})			
Control	9.4	2.0	1.8^{e}	13.6^{e}	1.0^{d}	2.5^{c}	11.4^{d}	3.0^{d}	0.7^{d}	10.4^{c}	11.8^{d}	1.9^{c}	18.2^{c}	91.5^{d}
100% NPK*	14.1^{a,b}	3.5^{b}	3.8^{b}	25.9^{b}	1.8^{b,c}	6.2^{b}	20.4^{b}	4.6^{b,c}	1.0^{b,c}	13.5^{b}	27.5^{b}	4.1^{a,b}	35.4^{a,b}	165.3^{b,c}
100% NPK + 15 t sludge ha^{-1}	15.3^{a}	4.3^{a}	4.6^{a}	30.8^{a}	2.3^{a}	8.0^{a}	25.7^{a}	5.9^{a}	1.4^{a}	16.4^{a}	37.4^{a}	5.2^{a}	44.1^{a}	223.4^{a}
50% NPK + 15 t sludge ha^{-1}	13.7^{b,c}	3.4^{b,c}	3.6^{b,c}	23.7^{b,c}	1.8^{b,c}	5.6^{b}	18.9^{b,c}	4.2^{c}	1.0^{b,c}	13.2^{b}	24.6^{b,c}	4.1^{a,b}	37.3^{a}	175.9^{b}
50% NPK + 30 t sludge ha^{-1}	14.6^{a}	3.9^{a,b}	4.2^{a,b}	26.7^{a,b}	2.1^{a,b}	6.8^{a,b}	21.6^{a,b}	5.1^{b}	1.2^{a,b}	14.6^{a,b}	29.8^{a,b}	4.6^{a}	39.0^{a}	200.9^{a,b}
75% NPK + 15 t sludge ha^{-1}	14.9^{a}	4.1^{a}	4.4^{a}	28.9^{a}	2.3^{a}	7.4^{a}	23.7^{a}	5.4^{a,b}	1.3^{a}	15.3^{a}	33.6^{a}	5.0^{a}	40.9^{a}	216.1^{a}
75% NPK + 30 t sludge ha^{-1}	15.5^{a}	4.3^{a}	4.8^{a}	32.1^{a}	2.5^{a}	8.5^{a}	26.1^{a}	6.2^{a}	1.4^{a}	17.2^{a}	39.3^{a}	5.2^{a}	44.8^{a}	242.7^{a}
15 t sludge ha^{-1}	11.0^{d}	2.6^{d}	2.4^{d,e}	17.2^{d,e}	1.2^{c}	3.0^{c}	13.7^{d}	3.6^{c,d}	0.8^{c,d}	11.6^{c}	14.7^{c,d}	2.5^{b,c}	24.7^{b,c}	109.3^{c,d}
30 t sludge ha^{-1}	12.4^{c,d}	3.1^{c,d}	3.0^{c,d}	20.2^{c,d}	1.4^{c,d}	3.8^{c}	15.4^{c,d}	3.9^{c,d}	0.9^{c}	12.4^{b,c}	18.7^{c,d}	3.2^{b,c}	30.0^{b,c}	132.3^{c,d}
$CD_{0.05}$	1.5	0.5	0.6	5.8	0.6	1.9	4.8	1.0	0.2	2.7	10.6	1.7	12.6	63.8

Data followed by the same superscripted letter are statistically similar at $P_{0.05}$

*100% NPK mean 100% recommended N,P,K for the crop.

Table 4: Effect of integrated use of domestic sludge and fertilizers on total nutrient uptake by maize (pooled 2008-09 and 2009-10)

Treatments	Total uptake (grain + stover)						
	N	P	K	Zn	Cu	Mn	Fe
	(kg ha^{-1})			(g ha^{-1})			
Control	14.9	3.4	29.2	41.5	5.8	50.6	253.3
100% recommended NPK	79.9	18.9	100.4	269.2	32.8^{b}	249.8^{b}	1135.8^{a}
100% recommended NPK + 15 t sludge ha^{-1}	108.8	28.7	137.2	401.3	47.1^{a}	349.8^{a}	1707.0
50% recommended NPK + 15 t sludge ha^{-1}	72.4	17.7	94.3	232.9	31.6^{b}	250.9^{b}	1157.9^{a}
50% recommended NPK + 30 t sludge ha^{-1}	89.2	22.8	111.5	297.2	38.1	281.0	1396.5
75% recommended NPK + 15 t sludge ha^{-1}	95.9	25.1	120.4	341.2	42.8	304.5	1546.8
75% recommended NPK + 30 t sludge ha^{-1}	116.9	30.1	147.2	434.2	49.8^{a}	364.8^{a}	1884.0
15 t sludge ha^{-1}	28.5	6.5	46.7	78.0	10.9	96.4	426.6
30 t sludge ha^{-1}	41.5	10.0	61.1	122.4	17.0	141.2	619.9
$CD_{0.05}$	2.6	0.6	4.7	20.4	3.1	21.1	104.0

[a,b]Data followed by the same superscripted letter are statistically similar at $P_{0.05}$

sludge treated soils when analyzed at crop harvest, but it was within the normal range of crop production. The decrease in pH could be ascribed to the acid production during sludge decomposition. The nutritional enrichment of soil could be due to the addition of sludge borne organic matter which acts as a sink and source of plant nutrients in the soil system due to its high nutrient buffering capacity. The beneficial effects of using sludge as an amendment/ manure on soil properties has also been proven by N'Dayegamiye (2009).

Conclusion: Recycling sewage sludge for use in agricultural sector to derive benefits from the nutrients and organic matter contents present in it seems a reasonable and rational way of managing this waste by-product which otherwise creates environmental pollution, and needs disposal through some other non-beneficial route. Domestic sludge @ 15 t in conjunction with 75-100% recommended

Table 5: Effect of integrated use of domestic sludge and fertilizers on soil health after harvest (pooled 2008-09 and 2009-10)

Treatments	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Nutrient status (kg ha^{-1})						
				N*	P*	K*	Zn	Cu	Mn	Fe
Control	7.2^{b}	0.12^{c}	5.3^{d}	205^{c}	16^{e}	302^{e}	0.9^{c}	1.8^{d}	12.3^{d}	13.6^{c}
100% recommended NPK	7.2^{b}	0.16^{b}	5.7^{c,d}	212^{c}	17^{d,e}	307^{e}	0.9^{c}	1.8^{d}	11.7^{d}	13.6^{c}
100% recommended NPK + 15 t sludge ha^{-1}	6.9^{a}	0.28^{a}	8.0^{a,b}	290^{b}	21^{b}	364^{b,c}	1.5^{b}	2.6^{c}	18.9^{b,c}	17.6^{b}
50% recommended NPK + 15 t sludge ha^{-1}	6.9^{a}	0.26^{a,b}	7.8^{b}	277^{b}	20^{b,c}	348^{c,d}	1.5^{b}	3.1^{b,c}	18.9^{b,c}	18.0^{a,b}
50% recommended NPK + 30 t sludge ha^{-1}	6.8^{a}	0.32^{a}	9.4^{a}	335^{a}	24^{a}	386^{a}	2.6^{a}	3.7^{a}	23.3^{a}	21.1^{a}
75% recommended NPK + 15 t sludge ha^{-1}	6.9^{a}	0.28^{a}	8.0^{a,b}	281^{b}	20^{b,c}	355^{c}	1.5^{b}	3.1^{b,c}	18.5^{c}	17.6^{b}
75% recommended NPK + 30 t sludge ha^{-1}	6.8^{a}	0.34^{a}	9.7^{a}	342^{a}	24^{a}	394^{a}	2.6^{a}	3.5^{a,b}	22.7^{a,b}	20.7^{a}
15 t sludge ha^{-1}	7.0^{a,b}	0.18^{b,c}	7.2^{b,c}	253^{b}	19^{c,d}	340^{d}	1.5^{b}	3.1^{b,c}	19.4^{b}	18.0^{a,b}
30 t sludge ha^{-1}	6.9^{a}	0.22^{b,c}	9.1^{a}	319^{a}	22^{a,b}	377^{a,b}	2.6^{a}	4.0^{a}	23.8^{a}	21.1^{a}
$CD_{0.05}$	0.20	0.10	1.8	23.6	2.8	21.8	0.4	0.7	4.0	3.1

Data followed by the same superscripted letter are statistically similar at $P_{0.05}$

*Available content and rest DTPA extractable

NPK or sludge @ 30 t ha^{-1} with 50-75% recommended NPK fertilizers may prove ideal in sustaining the productivity of maize in soils of Lesser Himalayas.

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